INFORMATION SYSTEM REQUIREMENT ANALYSIS AND SPECIFICATION IN FOREST MANAGEMENT PLANNING PROCESS

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Keywords: UML, Process Modelling, Requirement analysis.

Abstract: Forests cover up to 45% of the territory of Latvia and forestry is the most significant export sector in Latvia. The share of forestry in the country's Gross Domestic Product is up to 14%. In order to manage the forests economically efficiently it is necessary to plan the management activities for several decades in advance. The forecasting of tree growth takes an important place within the forest management planning process.
In order to develop IT solution for the process of forest management planning, it is necessary to perform the analysis of forestry sector, as a result of which the above models and also corresponding static structure are developed. For their development, the Unified Modelling Language (UML) specification and notation are used.

1 INTRODUCTION

Forestry is the leading sector of the national economy of Latvia. The increase of its efficiency is connected with the application of latest information technologies in forest management and planning in private and state forests. Taking into consideration the real criteria, the planning of forest management is a complicated and non-formalized process therefore, in order to tackle this problem, it is necessary to use IT solutions - such as object-oriented modelling with the application of the methods of artificial intelligence.

The necessity for the forecast of forest development several decades in advance is connected with the ensuring of sustainable forest management planning (FMP). Since FMP process is closely related to the time factor, the knowledge of forest estimation data after a particular period of time is an integral part of this process. Therefore there are solutions needed for the forecasting of tree growth process. The laws and regularities of the growth of forest stands form the theoretical basis for the forest management and are indispensable for the solution of several practical issues: determination of forest readiness (maturity), optimal felling cycle, choice of felling systems and its intensity, as well as target species for reforestation and afforestation, etc.

The aim of the paper is to develop IT solution for the optimization of FMP process. The following enabling objectives are set: the system analysis of FMP processes; the modelling of FMP processes, including tree growth motion prognoses.

2 MODELLING FORMALIZATION OF FMP PROCESS

Upon completion of the system analysis of FMP processes, it turned out that the model of FMP process (Use Case), as well as the corresponding static structure, should be developed. A significant part of the research is the modelling of FMP process, as a result of which the model of tree growth process should be implemented (embraced by FMP IS). The model of forest stand growth process is related to the actualization of the following estimation data: the age of forest stand, average height and diameter, the cross area of forest stand, the division of trees into subclasses according to the diameter, the number of tree stems per hectare, species composition and the quality of timber.

Dagis S. (2007).
INFORMATION SYSTEM REQUIREMENT ANALYSIS AND SPECIFICATION IN FOREST MANAGEMENT PLANNING PROCESS.
In *Proceedings of the Ninth International Conference on Enterprise Information Systems - ISAS*, pages 574-579
DOI: 10.5220/0002388505740579

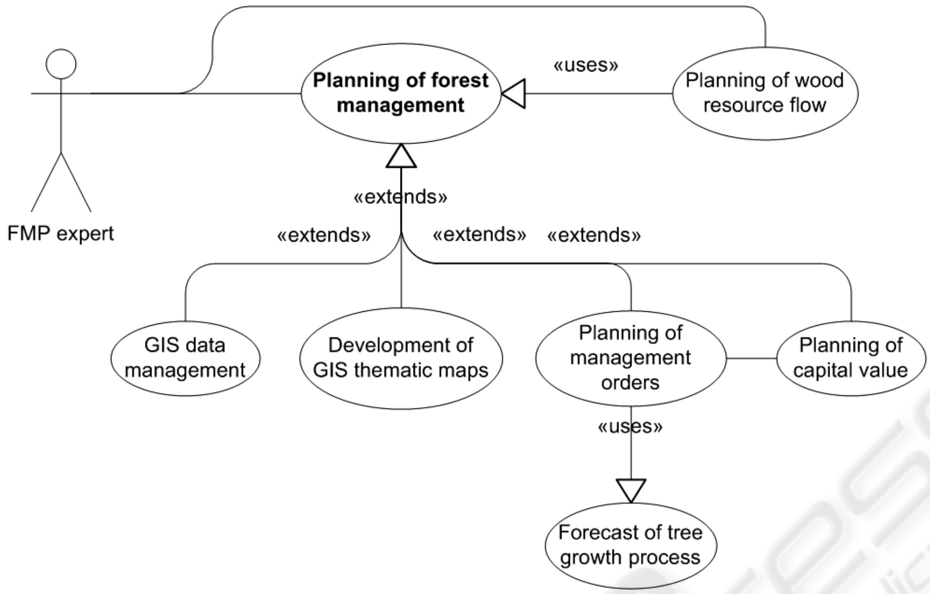

Figure 1: The dynamic model of FMP process.

2.1 The Dynamic and Static Models of FMP

The first step in the development of the system is defining requirements for the latter. As a result, there is the preceding model developed. The model is an excellent instrument for negotiation with the potential user about the system from the user's position. It is defined what the system intends to perform. The system requirements are the guidelines for its testing and assessing during the entire development process, as a result of which a qualitative system is obtained.

The forest management planning is performed by Actor – FMP expert (Fig. 1). This expert develops strategic plans by means of FMP algorithms and capital value algorithms. The above "Planning of capital value" is the basis for strategic plans, because the tactic and operational planning result from them. It is closely related to the tactic planning ("planning of management orders"), which suggests performing the following activities in the forest: reforestation of main felling, standing timber felling, forest stand, cultivation of young stands, etc. During the process of the planning of management orders, one should observe the Regulations issued by the Cabinet of Ministers, which contain restrictions on certain management activities (the age and diameter of the main felling, the maximum width and area of clear cut, the cross area to be left after sanitary cut, and other, regarding especially protected areas, etc.). A significant part of the restrictions on the forest management is related to the information analysis of geographic information system (GIS). Forest management plans, obtained at the operational planning level, are used to plan the wood resource flow (Oss, 2006) – it is where the transport cost is calculated and the wood resource flow recommended.

The above "GIS data management" ensures the correct input, modifying and mapping of GIS data. This is important because it supplements the functionality of GIS with the logic of forest territorial division (Dagis 2006a) and specific functions of space analysis.

The "Development of GIS thematic maps" envisage to facilitate the planning expert's functions, so that he knows the forest territories and their detailed description better. If the expert uses thematic maps, there is no need to see the estimation data of each sub-plot. It is possible to interpret the estimation data graphically, according to the requested criteria and thus develop thematic maps. When combining several thematic maps (the layers of GIS thematic maps), the group of thematic maps is formed. At this point, the data can be already analyzed according to several groups of criteria (the interlayer GIS data analysis).

The static models form the architectural basis of system. The diagrams of UML classes show the system classes with attributes and operations, as well

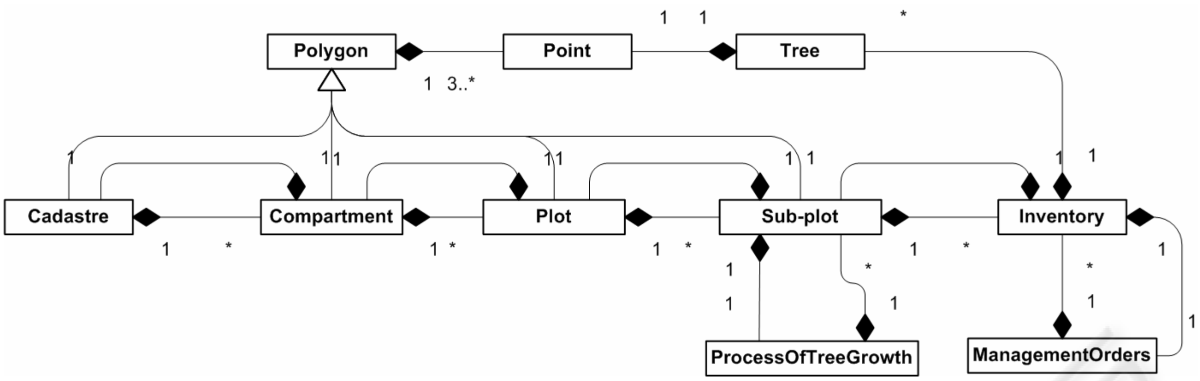

Figure 2: The static model of FMP process.

as the relations between classes. The diagrams of classes are usually used to define the concepts of research area, for the analysis of conceptual requirements and the process of object-oriented software development. In this case, the static model shows the interaction of research objects and their mutual relations. The essence of FMP process is the management orders, which form the basis for the planning of capital value, thus, the static structure of the above is developed (Fig. 2).

In each `Cadastre` there is one or several `Compartments`, each `Compartment` belonging to only one `Cadastre`. Similar correlations exist between `Compartment` and `Plot`, `Plot` and `Sub-plot`. All these classes of territorial division are inherited from the class `Polygon`. This ensures the possibility for data analysis with the GIS methods, which are from at least 3 or more points (x and y coordinates). `Sub-plot` is the base unit of forest territorial division, `Inventory` is related to `Sub-plot`. One `Sub-plot` can have several `Inventories`. Together with the `ManagementOrders, they` form `Sub-plot` history. Storage of the historical information in the system gives opportunity to compare the forest development and economic actions in time dimension, which, in the FMP process, gives adequate results. `Inventory` forms from inventory or inventory update process. `Inventory` is a set of trees, where each tree is geographically represented by a `point`. Each tree has attributive information (species, age, height, diameter).

In the process of management order planning, FMP expert uses territorial plans and forest estimation data. The activities that comprise this process, basically are carried out using the territorial elementary entities of forest – sub-plots (in special cases they are combined or divided into several `Sub-plots)`. A `Sub-plot` is a forest territory featuring trees with similar estimation indications (Sile 2006). FMP process is complicated and resources consuming, because a great number of FMP criteria, Regulations, issued by the Cabinet of Ministers, and forest owner's aims should be taken into account. The planning of management orders is mostly based on the analysis of estimation data and territorial restrictions. The estimation data should be topical within the planning process. The estimator's responsibility is to actualize the estimation data under real conditions once in 5-10 years, i.e. to visit the particular territory of forest and to perform the re-estimation. During these 5-10 years the development of forest continues, but the estimation data in the database do not change. It creates the potential error in FMP results. In order to avoid such error, it is necessary to update the estimation figures (without involving the resources of estimators), which in this case is modelled by the class `ProcessOfTreeGrowth`. One `Sub-plot` has only one tree growth motion (class `ProcessOfTreeGrowth`), but one tree growth motion can belong to several `Sub-plots`.

2.2 Modelling of FMP Processes

The model is a simplified description or the abstraction of reality. It is usually simplified, because reality is too complicated to be copied precisely. When developing simplified models, the main factors of influence are taken into account, while the insignificant ones are eliminated. When modelling processes, one should take into consideration the following basic principles: the developed models should reflect the actual situation precisely enough; the structure of models should be the one, which could be substantiated and used for the modeling of real processes. Mathematical or quantitative models are developed, when it is difficult and time-consuming to develop the physical model. Within the decision support systems the analysis is often performed numerically by means of mathematical models. The main reasons to use the mathematical models (Turban, 1988):

- They enable to analyze a great, and sometimes unlimited, number of possible solutions.
- They help to save time. The operations, which in reality take several years, can be performed in a shorter period of time using computer.
- It is easier to manipulate the model (change its parameters) than with a real system. It is easier to carry out experiments, the results of which do not affect the real system.
- The costs of errors, made during the experiments, are relatively lower than of those, made regarding real systems.
- The models enable to calculate the risk of specific activities.
- The costs of modelling are relatively lower than similar experimental costs of real systems.
- It is easier to show the obtained results of mathematical models graphically – easy to understand for everybody.

One of the most commonly used actualization mathematical models of forest stand estimation indicators in Latvia does not provide the result necessary for FMP process. For example, when actualizing average height and diameter of forest stand, the linear regression model of tree growth process is used $H(A+10) = a0 + a1 * H(A)$. It is stated that this model can be used only for the period of time, which is not longer than 10 years. Thus it does not solve the planning problem, where the estimation data should be actualized for the present moment and several decades in advance. At present widely applied model is linear and consists only of 2 parameters (a0 and a1), where the values are determined by the expert. Parameter *a0*, as a matter of fact, already shows the imperfection of the model, because the dimensions of any growing thing (height and diameter) at the age of 0 are equal to 0. Parameter *a1* indicates the rapidity of the increase of starting value. This model functions very well for the data actualization for a short period of time, i.e. the non-linear phenomenon could be described within the short interval by means of linear coherence. However, there emerges a problem concerning the use of these coefficients for the particular forecasting of tree growth process for a longer period of time, because the tree growth process within the full growth cycle is characterized by the non-linear coherence. Therefore, it would be necessary to determine the coefficients of linear equation repeatedly with a set step, if this model is used for a different age of forest stand.

The laws of forest growth that we know at present, do not fully reflect the essence of phenomena, and they have stochastic nature. Taking into consideration the great variety of nature, it is rather difficult to find the functional coherence in it. Therefore a law, defined mathematically, also characterizes a separate object only approximately. In order to describe any regularity in a mathematical form (as a mathematical formula), it is necessary, first of all, to find a general form of this mathematical formula and then, using the experimental data, calculate the parameters of this formula. The level of modern computer engineering (software provision) enables to calculate the parameters of formulae without any difficulty, while the informed choice of the general form of equation is a yet unsolved problem. It is especially related to the multiple stochastic coherences, which one often comes across in the research in the area of modelling growth process. In case with mathematical models, it is necessary to describe the conditions, under which these models are characterized by persistent functioning and are able to provide correct results.

A research performed recently, (Dagis, 2006b) concerns the mathematical models of tree growth process, where the following non-linear regression models of these process were studied:

$$y(t) = a \cdot t^3 + b \cdot t^2 + c \cdot t \quad (1)$$

$$y(t) = y_0 \cdot e^{-b \cdot t} \quad (2)$$

$$y(t) = a \cdot t^k / (b^2 + t^k) \quad (3)$$

The third polynomial level (1) is viewed, as it provides good correlation coefficient within the process of approximation. The polynomial coefficient has no biological meaning and it does not represent any growth model, therefore its application is irrelevant. The exponential model (2) has biological meaning, it models the limit of tree growth in time: when increasing the age of tree growth *t*, the speed of growth has a tendency towards zero. But, unfortunately, when approximating, the correlation coefficient is not as good as it is in case with Power model (3). Power model excellently approximates experimental data with a good correlation coefficient. This mathematical model was determined as the best one for the further use to model the tree growth process.

3 RESULTS

The static model of FMP process was implemented - FMP IS "Forest expert". This IS was developed as a result of several research projects and at present serves as an instrument of FMP process.

The implementation of forest territorial division static structure is shown in Figure 3, where, on the left, there is the forest territorial division (cadastres, compartments, plots, sub-plots), but on the right – the implementation of the above mentioned mathematical Power model of tree growth process with the real estimation data. These estimation data are obtained from several districts of Latvia, with the total area of 59,904 hectares, (41,056 sub-plots), the prevailing species is pine (47% of total area), the dominant types of growth conditions – pine forest with *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest. Estimation data were obtained from 1999 till 2005. These territories are mostly characterized by II quality of locality (34% of total area), which is a man-made division entity for the characterization of forest stand productivity, determined by the tree height at a particular age. Figures from 0 to 6 (usually – Roman numerals) are used to label the quality of locality of stand. The highest quality of locality is 0 or Ia, the lowest - 6.

In order to use the model of tree growth process, it is necessary to specify the coefficients with the input parameters, determined by the model. It is necessary to choose the species, the type of growth conditions and the quality of locality (Fig. 3, *C*). As a result, the average contour line and diameter data of forest stand, grouped by decades, are selected from the available in the database (Fig. 3, *A*). On the basis of the selected data, using Power model, the coefficients of model are calculated, and the result is shown as a graph (Fig. 3, *B*), where two curves represent the real estimation data (tree height and diameter) and another pair of curves shows the approximated values of model.

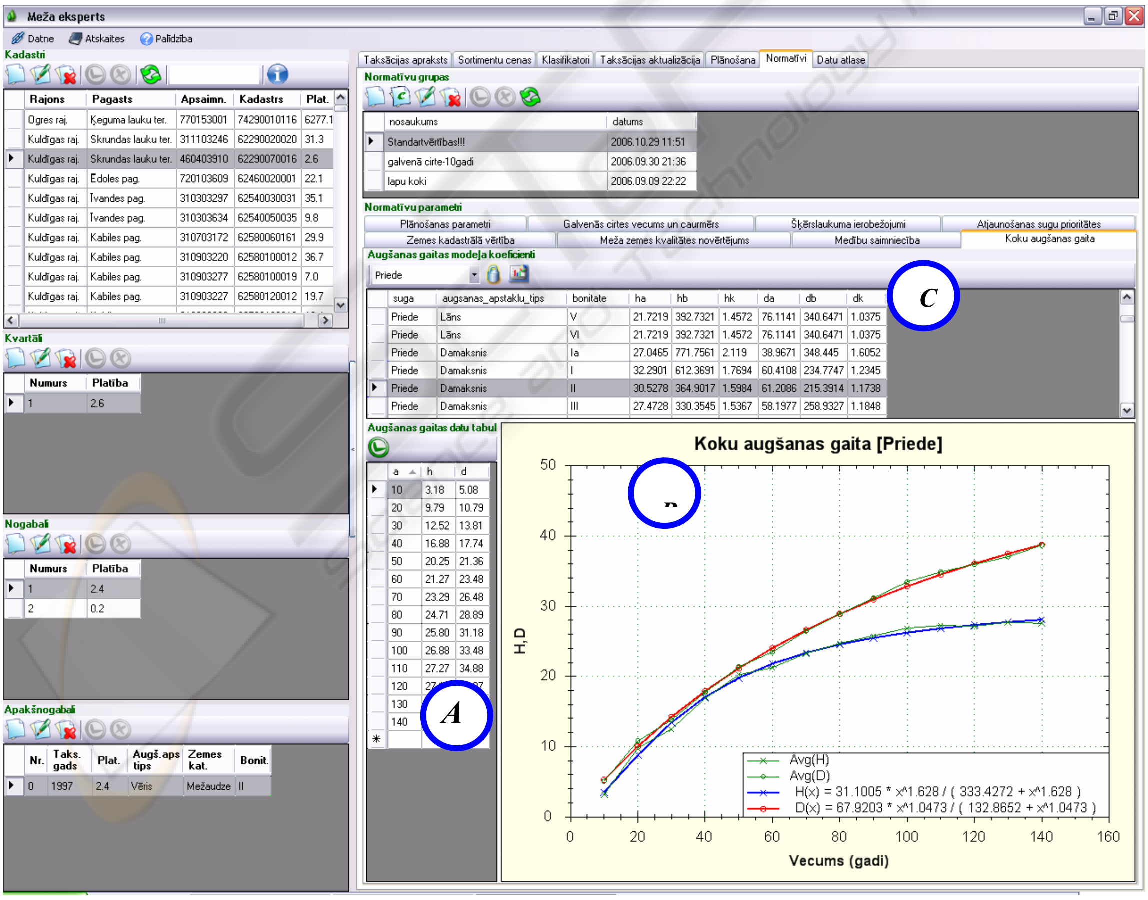

Figure 3: IS implementation of the mathematical models of tree growth process.

This Power model functions under particular conditions, i.e. the model characterizes the tree growth process of chosen species under a particular type of growth conditions and quality of locality, therefore, it is necessary to calculate the coefficients of mathematical model for all possible combinations.

4 CONCLUSIONS

Using the dynamic model helped to define system requirements for the execution of which the static model was developed. One of the essential features of the static model is the implementation of tree growth by means of nonlinear mathematical model. It was necessary to employ these models, because it is impossible to perform experiments with a real system – forest - within FMP process. Using implemented mathematical model and adding to it the statistically obtained coefficients, it is possible to forecast the development of forest stands with similar indications – in different types of growth conditions and qualities of locality. The growth process of trees is modelled with mathematical equation $y(t) = a \cdot t^k / (b^2 + t^k)$, where the characteristic is always increasing with 2 bending points, therefore, it eliminates the occurrence of possible incorrect data.

During the calculation process of mathematical model coefficients, the following condition is to be met: the data must be sufficient or, when grouping data by decades, each decade should be represented by at least 3 average estimation records – depending on the limit of negligible forecast error. This condition emerged, while testing model according to particular estimation data, when it was stated that the estimation data may have errors and deviations from the average indicators, as long as there are particular input parameters.

Such a model of growth process can be applied to the analysis of difference in the forest growth process of separate regions, as well as to the search of incorrect, faulty estimation data in the existing estimation database.

The static model of FMP process and mathematical model of tree growth motion was implemented (FMP IS “Forest expert”). Such a tree growth motion forecast model can also be employed in other states. For the complete ensuring of FMP process, it is necessary to develop GIS module, which would implement the territorial limitation of FMP.

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